XII. *The life-history of the Hessian Fly*, Cecidomyia destructor, *Say*. By Frederick Enock, F.E.S.

[Read February 4th, 1891.]

Plate XVI.

In the 'Third Report of the United States Entomological Commission, 1882,' there is a long paper compiled by Dr. A. S. Packard, on the Hessian Fly, concluding with a list of no less than seventy-one papers and articles on this insect; and since that date the number has gone on increasing, so that up to the present time it cannot be far short of one hundred! This being so, anyone would naturally suppose that the subject had been thoroughly worked out, with every detail of the life-history laid bare, until nothing more could be learned about it; and I dare say that many may think it presumptuous on my part to attempt to say anything new. My reason for bringing this matter before you is—that of all those who have written upon the Hessian Fly, since Mr. George Palmer, of Revell's Hall Farm, Hertford, first discovered it in England, on July 27th, 1886, none of them have given any account of its life-history from their *own* observations, but have preferred to copy the writings of others, and, in so doing, have copied their mistakes.

Before entering upon a detailed account of the notes and observations which I have made during the past four years, I will throw upon the screen a photograph of a barley plant, taken from a field at Revell's Hall Farm, in which you will observe that the stem is bent down sharply at the second joint; this has been caused by the larvæ of the Hessian Fly (*Cecidomyia destructor*, Say), and it was this appearance of bent and broken stems which first attracted the attention of Mr. Palmer, who at first thought the barley was merely "root-fallen"; but a more careful examination of the bent stems revealed the peculiar chestnut-coloured "flax-seeds" which Prof. Westwood and others identified as the puparia of the Hessian Fly.

Most of us here present will remember the fear and great trembling which seemed to fall upon some entomologists, farmers, and others; and "reports" came in from various quarters, all kinds of ingenious explanations being given as to why it had appeared in one county and not in another—the fact that "the pest" had wings and could transport itself whithersoever it felt disposed being quite overlooked; and I am inclined to think that had we had in Great Britain a properly organised staff of practical entomologists, with agents in the country, such as the United States of America have, our Government "Reports" would now be looked upon with a little more respect than they are by foreign entomologists.

It is very often the case, when an entomologist sets himself the task of following out the life-history of any particular insect, that he becomes acquainted with its *last* stage *first*, and the *first*, *last*; though the subject of my discourse made itself known to us first in its so-called puparia or third stage, and this appears to have satisfied most "arm-chair" naturalists.

My first acquaintance in the field with the now well-known "flax-seed" was made on August 5th, 1887, when invited by Mr. G. Palmer to visit his barley fields, and many times since then have I enjoyed the kind hospitality of Revell's Hall.

I will now commence the life-history of the Hessian Fly by giving my notes and observations made upon the *first* stage, *viz.*, the egg. On Sept. 8th, 1888, I visited Revell's Hall Farm, and examined the stubbles in one of the barley fields, which had only been cut a day or two previously, and here I very soon found the eggs on both self-sown plants and aftergrowth. I immediately settled down to serious work, and, whilst so engaged, I observed a small dark fly meandering about the stubble close to the ground; after following it for some yards I lost sight of it near some aftergrowth, from which I started it up again, and finally lost it among a heap of cut barley. On examination of the self-sown plants I found a number of eggs had been laid thereon.

Wishing to arrive at some definite conclusion as to whether the fly preferred the self-sown plant or the "aftergrowth," I gathered a hundred of each. I then most carefully examined each leaf on both sides with my pocket-lens, commencing with the self-sown, most of

which had but *one* blade, or at the most *three*, varying in length from an inch and a half to three inches high, showing that they were of very recent growth. I found eggs on 21 of them, *all* laid on the youngest or last developed leaf; these I subjected to a more minute examination on reaching home; the total number of eggs being 113, or an average of 5 to each self-sown plant, the actual numbers varying from 2 up to 12 on a leaf. Of the 100 plants of "aftergrowth," most of them 6 to 9 in. high, and having 4 to 6 leaves, only 12 had been attacked; the number of eggs laid was 84, or an average of 7 to each plant, showing the marvellous instinct (or whatever else we may term it) of the fly, which, in the case of the delicate self-sown plant, only laid 5 to each, but seem to know that the stronger *aftergrowth* was capable of sustaining more; the number of eggs laid varied from 2 to 20. On 9 these were laid on the last developed leaf, and on the other 3 the eggs were divided, and laid on the last and preceding leaf: leading me to think that *two* flies had visited these three plants. Most of these eggs hatched in less than a week.

On Sept. 22nd, 1888, I found great numbers of eggs on both self-sown and aftergrowth barley around Stroud, Gloucestershire, where I also found puparia in the stubble, and great numbers in the wheat; in fact, in *every* barley and wheat field which I examined around Stroud during a fortnight's visit to Mr. Thos. Lancaster, of Bownham House, I found eggs and puparia in the greatest abundance, besides capturing a number of specimens of the male Hessian Fly on the windows. This is the first time "the pest" had been reported from the West of England, though no doubt it had been firmly established there, as I am inclined to think it has been all over the country, for some time; and if farmers could be persuaded to search for it, I think it would be found all over England and Scotland, and in all probability in Ireland too.

As it would be impossible from *out*-door observations to determine the number of eggs a female fly is capable of laying, we must fall back upon experiments conducted somewhat under difficulties and artificial circumstances, owing to the surroundings of a small London garden not being quite so countrified as we could wish.

From puparia which I collected on Aug. 5th and 8th, 1887, I bred a large number of male and female flies,

and on June 4th, 1888, I placed an impregnated female under a separate cylinder of book-muslin, a foot high by 6 in. in diameter, carefully fitted and fixed over a flower-pot containing a dozen young plants of barley of four days' growth; in a few moments after being introduced, the female settled on one of the plants about 2 in. high, and commenced ovipositing as fast as she could: by first placing three eggs side by side, then at a short distance three more close together, then six on the outside of the sheath of the stem, and, apparently becoming excited, she laid clusters of three, four, and six; seven more on the outside, and five at the tip of the leaf: thirty-seven in all on this one plant; she then flew to No. 2, laying

16 on the inside of the leaf, and 10 on the stem	.	= 26
No. 3. 4 outside, and 11 on the inside of leaf	. .	= 15
,, 4. 24 on the inside of leaf, some in clusters	.	= 24
,, 5. 10 ,, ,, ,,	.	= 10
,, 6. 6 outside sheath, close together, & 12 inside.		= 18
,, 7. 14 ,, ,, ,, 14 ,,	.	= 28
Total	.	158

eggs laid by this one female, which is greatly above the number stated by most writers, Herr Wagner included; he gives the number at 80 and under 100.*

On July 29th, 1888, I isolated another female immediately after impregnation at 2 p.m., when she commenced to oviposit on the barley plants, continuing to do so until 7 p.m.; on examination of the leaves, I found she had laid 23 eggs on the outside of 12 leaves, and 106 on the *inside* of 27 leaves; total, 129. The next day the fly appeared to be laying eggs on the muslin, but I could not get my lens near enough to detect them.

Aug. 3rd, 1888. I put six females under a cylinder, but, as I went to Hertford that day, I had not an opportunity of watching them or examining the leaves until the following day, when I found 38 eggs had been laid on the *outside* of 10 leaves, and 228 on the inside of 21 leaves, varying in number from 1 to as many as 44 on a single leaf. These females did not appear to have completed ovipositing, and for some reason would not continue.

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* 'U. S. A. Third Report.' Appendix, p. 15.

On Aug. 5th, one female laid 80 eggs on one leaf 2 in. long, and another 100 in a small phial.

Aug. 6th, a female laid 58, and another 140 eggs.

On the same date I placed six impregnated females in separate phials, where each one commenced to oviposit freely, placing the greatest number on the under side of the corks. No. 1 laid 130; No. 2, 125; No. 3, 129; No. 4, 114; No. 5, 96; and No. 6, 70 eggs.

I will not weary you with further details of oviposition, as those I have given show that the female Hessian Fly lays from 100 to 150 eggs, distributing them over many plants, and depositing them end to end in rows of 3 to 10, sometimes side by side, and at others carelessly in clusters.

On Sept. 13th, 1888, I dug up a fresh root of wild oat-grass (*Arrhenatherum avenaceum*), and re-set it in a pot of sandy soil, covering it over with a cylinder of book-muslin; I then introduced some female flies, and one soon settled down to ovipositing on the upper surface of the leaves; but I noticed a peculiar uneasy movement of the ovipositor, as though the fly was not quite satisfied that it was a suitable plant; and when some fresh *barley* leaves were introduced, she immediately recognised their presence, becoming quite excited and utterly careless in her hurry to lay her eggs, most of which were in clusters or, I might say, lumps. On Oct. 14th I made a careful examination of the grass, but could not find any trace of larvæ, so concluded the stem was too hard and dry for them to subsist on. Prof. C. Lindeman, of Moscow, has found the puparia on Timothy-grass (*Phleum pratense*).

I have made most careful microscopic measurements of the fresh-laid egg, which is ·02 mm. long by ·008 broad; it is rounded at both ends, of a pale orange colour, with reddish dots here and there, making it very easy to be seen in the ridges of the young barley-leaves; this colour soon changes to a somewhat darker hue, the shell becoming so transparent on the third day that the movements of the enclosed larvæ can be distinctly seen; and on the fourth day I have often watched them making muscular efforts to burst open the shell, which they succeed in doing after three or four hours' work.

The female fly, as a rule, lays her eggs with the head-end pointing downwards towards the main stem, so that when the tiny larva emerges it is started from its infancy

in the right direction on its journey downwards, and, guided by the longitudinal striæ of the leaves, it reaches the stem, round which the leaf-sheath is closely wrapped, but not too close to prevent the larva forcing its way; until, after some four hours' steady travelling (during which time it has covered only the small distance of two or three inches), it reaches the base of the sheath, generally of the second joint above ground; here its further progress is blocked, and it turns half round, so that its ventral surface is in contact with the stem, the head still downwards.

As idleness in insects is a characteristic noticeable by its absence, the tiny larva commences to injure the plant by bringing its head and mouth up to the soft stem, imbibing the life-juice for its maintenance, but very much to the detriment of the barley. The larva increases in width even before it disappears out of sight, leading one to suppose that it imbibes moisture as it journeys down the furrows of the leaf; that the larva *is* capable of taking fluid nourishment I have proved by feeding and fattening a number of them which emerged in a glass phial, Aug. 7th, 1888, into which, attached to the cork, I put a strip of white blotting-paper, which I had moistened by dipping into a very weak solution of starch-water; the damp paper clung to the sides of the phial, and between the paper and glass a number of the young larvæ crawled, and lived upon the starch-water for more than a week. I am afraid, when withdrawing the cork to replenish the blotting-paper with starch-water, the larvæ received some injury, for all were dead on the eighth day. I frequently observed that when an impregnated female was put under a cylinder enclosing growing barley she showed considerable excitement, and was careless as to where she laid her eggs; sometimes settling on a leaf bent down, laying her eggs the *wrong* way, with the heads towards the *tip* of the leaf.

I watched the eggs very closely on the fourth day, and was fortunate in seeing some hatch. The larvæ worked their way to the tip of the leaf, where some of them managed to cross the edge and get on to the back or under side, and commenced their tremendous journey of four to six inches! some arriving at their destination at the next joint *below* the one they would have occupied had the female laid her eggs on the inside of the upright

leaf. The progress of the young larvæ was very much accelerated when the leaf was moistened, and many died on a hot, dry day.

Some of the "one-day-old larvæ" I mounted in fluid, and the one now before you shows the head and organs of the mouth as seen from above, and the other seen from the side (Plate XVI., fig. 1). From these you will observe that the mouth of the *young* larva appears to consist of a notched semicircular plate, at each side of which are the palpi. At the anal end there are indications of suckers, or prehensile feet.

Larvæ measured Aug. 9th, bred Aug. 7th, were 2 mm. long. On Aug. 23rd I examined some of the young barley plants growing in pots, upon which a number of eggs were laid Aug. 8th: at one joint I found three larvæ, and at the second joint of another no less than nineteen of various sizes, packed close together.

On Aug. 8th eggs were laid by a female, and hatched on the 12th; the larvæ full grown Sept. 6th, when I noticed some were beginning to change colour; this gives 25 days as the feeding-time of these larvæ in confinement.

A good deal has been written about the so-called "anchor-process," or "breast-bone," which is (according to Miss Ormerod):—"A short stem fixed at one end to the larva, and free at the other; the free end, which points forward, is considerably enlarged, and is of various forms . . . . . but the use of this appendage does not appear as yet to be fully known; but from my own observations I conjectured that it is used as a digger or scraper, and it may be that the reason why strong-stemmed wheat, or stems containing more silica, are not so much injured by attack as other kinds is that the fork is not strong enough, in these instances, to assist the excessively delicate mouth-parts to acquire their food from the stem."

And again, in our *one* "Official Report," which was "presented to both Houses of Parliament by command of Her Majesty"! we read, at p. 12:– "From the eggs laid in the spring comes a wrinkled yellowish maggot, the larva, without legs, having fourteen joints. It is close upon the eighth of an inch in length when full-grown, being then of a clouded white hue, and showing faint greenish lines under the skin. The

anchor-process, or breast-bone, upon the second segment next to the head, on the under surface of the body, is also plain and prominent. This is a forked appendage, mistaken by Curtis for two rudimentary legs, and is peculiar to the larvæ of the *Cecidomyiæ*. It is probably used to assist the larva, whose mouth is soft, in penetrating the tissues of stems of corn-plants. After the larva has been hatched, it proceeds from its birth-place on the leaf above almost invariably to the second joint of the stem at the base of the blade or leaf, and fixes itself head downwards, with its head close to the soft stem, and with its rudimentary mouth, *and its anchor-process* (italics are mine), as is supposed, absorbs the juices of the plant."*

To most of those who have read the two pamphlets from which I quote the above, these statements may appear perfectly correct; but anyone who will take the trouble to carefully examine under the microscope the *true* larva (Plate XVI., figs. 2 & 3), (by this I mean the larva in its first or *feeding* stage) will at once see that it does not possess any anchor-process at all, and it is not until the *final* larval stage, when the larva is securely sealed up within the puparium or coarctate larva, or second larva stage, that the anchor-process is developed and utilised in the most wonderful manner.

I will now throw upon the screen a photograph of a feeding larva, showing the invaginated head (Plate XVI., fig. 3), and would call your especial attention to this wonderful provision of Nature, the mouth being so constructed that it acts like a spiral spring; and whatever the pressure of the leaf-sheath upon the dorsal surface, the mouth is kept just up to its work, and adapts itself to the varying pressure—another example of the skill of the Great Artificer, which cannot fail to excite our admiration and wonder.

On Aug. 15th I collected a number of coarctate larvæ, as well as some larvæ still feeding in the aftergrowth, or any green plants; these I carefully examined, as well as the nineteen found at one joint, for the purpose of deciding to my own satisfaction which way the larvæ rested; for all writers in America and elsewhere state that the larva rests head downwards, and yet not one of the number has ever explained how the fly emerges.

* See 'Whitehead's Report,' p. 12.

Perhaps it will not be waste of time to consider the position of the larva when feeding. The head and mouth-organs of a new-born larva are, as you will see from the photograph, placed at the extreme end; but if we examine a full-grown larva, we find the head has become invaginated and bent round almost at right angles to the body, so as to bring the mouth-organs into contact with the stalk of the plant, and as the juices are imbibed the cells become partially withered, forming a cavity in the stalk, in which the larva is embedded, or pressed into, by the encircling leaf-sheath.

I must confess that when I read that the larva fixes itself head *downwards*, I felt rather incredulous, for I immediately thought, if this be so, How does the *fly* emerge? for, as you see from the photograph (Plate XVI., fig. 9), the head of the larva is *downwards* and turned *inwards*, fixed into the solid stem; and, even supposing that the pupa was capable of penetrating this, it would only land itself in the centre of the hollow stem, with a solid joint top and bottom to bar further progress. I then thought that surely the larva must, as soon as it reaches the joint, immediately reverse its position, keeping its head *up*, and then there would be no impediment in the way of the fly when emerging. I examined a number of half-grown larvæ most carefully, and could not then come to any other conclusion but that they had been wrongly described as having their heads downwards, and this idea was considerably strengthened when I bred several of the flies, for on examination of the puparia I found they *had* emerged at the top end

On Sept. 6th, 1888, I examined some of the home-grown barley plants, and found six larvæ at one joint; one of them was full grown, the colour glassy-white, with the usual greenish intestine, the skin perfectly tight, so that the segments were scarcely visible. I laid this specimen on its back for the purpose of making an exact drawing, and, whilst engaged measuring the lower or thick end with the eye-piece micrometer, I was astonished to see through the skin, immediately below the orifice (which I had imagined was the tail), the anchor-process in motion. This discovery—to use a somewhat unscientific expression—"sent my heart into my mouth," for I had a strange feeling that I was on the point of clearing up a great difficulty; for as this apparatus, the

anchor-process, is placed in close proximity to the head of the larva in the *third* stage (Plate XVI., fig. 5), and the fly emerges at the top end, it proved that the larva in its *third* stage *turns head to tail within the puparium*, and its head, which when feeding was pressed against the stem, is now brought to the opposite side and end, facing outwards and upwards (Plate XVI., figs. 9 to 16). At the time of this discovery I made a note that it seemed to me that the anchor-process was in some way used by the larva to assist it in turning round.

On the following day, Sept. 7th, 1888, I examined a number of barley plants, removing therefrom all the full-grown larvæ, of which there were great numbers, and in most of these I could see the anchor-process under the invaginated head, fully confirming the previous day's discovery; these larvæ gradually assumed the coarctate state, and in a fortnight had become of a chestnut colour; these and many others taken from the barley plants I fixed to a piece of card in the same position as they occupied when feeding—with heads *downwards*.

On Sept. 7th I also dissected seven puparia collected since July 5th, and in one case the anchor-process was found at the upper end, proving beyond a doubt that the larva had turned round. Another which I dissected revealed the *true* pupa, with its head up and facing outwards; the perfect insect emerged in about ten days after, and the other six a little later.

Of the puparia fixed on card, I opened one or two at regular intervals of about a week to see if I could catch a larva in the act of turning round. The first examined, Sept. 13th, had the anchor-process still at the lower end, and subsequent examinations made all through the winter and up to April 5th, 1889, showed the anchor-process to be still at the lower end; but on April 20th I examined some, and found no sign of anchor-process at the lower end, so dissected the *other* end, and, on removing the skin, discovered that the larva had turned round, the anchor-process now being seen at the top end outwards; and *all* examined after this date, April 20th, had turned round, and during May many were found to have changed to pupæ. From the foregoing observations I gather that when the larva arrives at full growth and leaves off feeding, and coincident with the gradual hardening of the skin and change of colour from white to chestnut-brown, is the wonderful change *within* the

coarctate larva. Careful dissections and removal of the outer skin reveals the larva in its final larval stage; the smooth shuttle-shape remains, but has no connexion with the enclosed larva, which has shrunk away from its former covering, *just as a ripe nut does from its shell*, and is now somewhat flattened and much wrinkled in form, with blunt ends; the head, which in the *feeding* larva was decidedly turned so that it was on the side, has now recovered its primary position at the end, and immediately below this, in front, on the second segment, is the anchor-process, a photograph of which I will now throw upon the screen (Plate XVI., fig. 6). From this front view you will observe that the fixed part of the apparatus lies partially embedded, the tips just projecting beyond the top of the segment.

Though my endeavours to catch a larva in the act of turning round were not successful, I made some valuable observations from the contortions of the disturbed larvæ, the most important being that, by a powerful contraction of the muscles attached to the lower part of the anchor-process, the larva was enabled to draw the apparatus in at the base until it was at right angles to the normal position; the head, too, was drawn *quite* in, so that the forked end of the anchor-process projected to its fullest extent, and whilst in this naked condition it is thrust into the inside walls of the coarctate larva; the muscles are relaxed, and the ventral surface brought into contact with the inside ventral surface of the coarctate larva. Then other muscles appear to move a portion of the dorsal surface of the body downwards and round towards the bottom or head-end of the coarctate larva; the tips are then withdrawn, the base contracted again, and a hold taken by the tips being driven in a little higher up; again the muscles bring a tiny portion of the body further round and down, and so this leverage goes on until the larva has completed its task, reversed its position, and rests with its head *up* and anchor-process *outwards;* the spines on the skin of the larva, all of which point down towards the base, assist it materially in obtaining a firm hold on the inside of the coarctate larva, preventing it from slipping back.

On July 31st, 1889, I received from Mr. Stewart a number of pieces of the common reed grass (*Digraphis arundinacea*); on the outside of the stems

were a number of longitudinal slits of about $\frac{1}{8}$ in. long; on cutting the stem through, I found at the back of each of these slits a hard sort of internal gall, containing a flattened and wrinkled larva very much like that of the Hessian Fly, only twice as large; the anchor-process was very prominent; its movements exactly similar to those noticed in *C. destructor*. Having obtained a large supply, I endeavoured to cut the outer wall of the gall so that I could watch the movements of the larva, and at last, after endless failures, I succeeded in just cutting through and removing sufficient of one side to expose the larva; this I placed on the stage of my microscope in such a position that I could, with the aid of the "silverside-reflector," throw a most brilliant light into the interior. When first exposed, the larva was lying perfectly quiet in a horizontal position, but after some hours' watching, it slowly raised its head, then withdrew it out of sight; the tips of the anchor-process were brought into contact with the inner surface of the cell, followed by a movement and contraction of the base, exactly similar to that which I had observed in the larva of the Hessian Fly; it then appeared to fix the tips into the cell; the base of the apparatus appeared again, and the 3rd and 4th segments could be seen moving in the direction of the head; a slight pause, then the anchor-tips were next withdrawn the merest distance, and advanced very slowly; the muscular contraction repeated, and the points driven in, followed by a decided movement of the 3rd and 4th dorsal segments; these movements were continued until the larva had worked itself a little beyond right-angles, when it paused in its work, and gave me the opportunity for making a careful sketch; and though I watched it long into the night, it did not increase its position; possibly the aperture I had made had in some way interfered with its comfort, and it objected to be stared at with so high a power as 40 diameters! But I think I had observed enough to warrant me feeling sure that I had determined the use of this anchor-process, which at first sight appears of little importance, but when carefully and patiently studied proves to be of the highest importance, enabling the larva to extricate itself from a position which to me seemed incomprehensible.

I have bred a great many flies from the puparia which Mr. Palmer has so frequently sent to me, and most of them emerged from the dorsal side between the 10th

and 12th segments, but some had emerged at the other end; these I carefully examined, and found that the fly had emerged on the ventral side, or that nearest to the stem, showing that in these instances the larva had *not* turned round, and it would in all probability have perished had not the puparium become detached from the surrounding sheath. A few had emerged at the dorsal side, appearing to have revolved half-way round, so bringing the head to the front and outwards, though *downwards;* but in *every* one of the hundreds bred from coarctate larvæ in their normal position in the straw, the fly had emerged at the *top* end.

On July 5th, 1888, the larvæ were most plentiful in the barley, and as the crop was very backward and stunted in *May*, when the females were ovipositing, the larvæ in nearly every one of the 400 straws cut were not more than an inch above ground, and in many instances the barley was bent *at* the ground-line.

I noticed that the small thin plants were more frequently attacked than the stronger ones, and generally contained several larvæ; the tail-end protruding from between the folds of the leaf-sheath. The position of the larva was quite different to that in the 1887 crop, when the barley was much stronger and the bend nearly always at the second joint, and often at the third, 7 to 10 in. above ground.

The larva is most delicate, and dries up if the straw is cut before the maggot has reached its full growth; so that the only plan to observe the changes is to have a number of living plants of various sizes; in fact, when the flies are emerging, sow about a dozen grains in a six-inch pot, always keeping up a constant supply.

The second stage of the larva, known as the puparium, or, more correctly, the coarctate larva, and more popularly as the "flax-seed" state, has been so frequently and fully described that I need not add to it; but one thing I have constantly noticed is that when the leaf-sheath is removed carefully, and the upper or tail-end of the flax-seed drawn away from the stem, the mouth always appears to be fastened by some sort of white cement or starch, which in a measure prevents the puparium from being too readily shaken out of place before its time; though no doubt vast numbers are scattered broadcast when the harvest is cut and carried, and, wherever the

waggon goes, there the puparia are shaken out, and I have found them lying free on the ground underneath the shocks of barley.

The number of larvæ at the joints varies considerably —from one to nine in straw collected at Hertford, and in home-grown plants, in *one* instance only, as many as *nineteen!*

The male puparium is of a much more slender form and paler colour than that of the female.

When the crop of barley is backward, as in 1888, a great many puparia are left in the stubble, and should the field be sown with clover, they remain in the stubble all the winter, secure from injury; the flies which emerge after the harvest have no difficulty in finding plenty of aftergrowth and self-sown plants growing among the clover, and on which they lay their eggs.

Owing to the time of year when the wheat and barley are sown, the females are all dead before the wheat is up; but not so in America, where whole districts of "fall-wheat" are entirely ruined.

On Dec. 31st, 1888, I received from America a tin box which contained a large number of plants of this "fall-wheat," a very slight examination of which revealed a number of puparia close round the base of the stem, and in some cases there was a slight appearance of a gall-like swelling. I put these plants under a cylinder of muslin, and exposed them to the full force of the weather. From May 5th to the 22nd I bred forty-four male and thirty-seven female Hessian Flies, and from June 5th to July 5th twenty-three parasites, *Platygaster minutus*.

Herr Wagner, in his admirable Monograph on the Hessian Fly (a translation of which appears in the Appendix to the 'Third Report of the U. S. A. Entomological Commission'), states that:—"Though the great frequency of the parasites in the summer generation was striking, it was not less so that the pupæ gathered from the barley aftergrowth yielded not a single parasite, from which I infer an entire exemption of the actual winter generation (not to be mistaken for those hybernating in stubble) from parasites. Fitch received from young infested plants gathered in April only gall-gnats, thus corroborating my idea that the parasites attack only the winter generation."

I venture to think that Herr Wagner did not obtain a sufficiently large number of plants, or he would no doubt

have bred the minute parasite, *Platygaster minutus*, which, by the bye, can force its way through the meshes of the finest book-muslin, and only a cambric pocket-handkerchief tied over the cylinder will keep them in.

In the table given later on of the parasites bred, you will notice how very few emerge in September and October, and I think that one reason why the "fall-wheat" is so free from parasites is that they could not get down to the puparia, which are close to the roots; but I have repeatedly watched these small *Platygaster minutus* searching for and sounding the lower part of the stems for puparia, and, failing to find them, they have worked their way down the smallest space between the stem and surrounding earth, and no doubt reached the objects of their search.

The plants of "fall-wheat" sent from America were so dried up and brittle that when I attempted to search for puparia their position could not be accurately noted; but in infested plants of a similar size grown in pots, and on which the eggs were laid before a stem was formed, I found the puparia at the roots, and in some instances lying in the old husk of the grain, and others actually underneath the crown among the roots. The photograph of American "fall-wheat" shows the empty pupæ-cases protruding from the stems.

In only *one* instance have I found puparia at both 2nd and 3rd joints of the same plant, at Stroud, Oct., 1888. From about 500 infested straws gathered, I noticed a great many puparia were at the 3rd joint, at least nine inches from the ground, and that the barley at each side of the roadway through the fields was always most affected; this, to my mind, was the result of the previous year's scattering of puparia from the waggons at the time of carrying. I particularly noticed this at Hertford, Littlehampton, and many fields around Stroud, Gloucestershire.

The next stage is the third larval, or rather final larval, form, which is most easily obtained by placing on damp blotting-paper or sand a number of puparia picked out from "screenings"; these are more or less injured by having passed through the thresher, and the effect of moisture upon a fractured puparium is most striking, causing the larva to work its way out, and, when entirely free, it quietly rests in some cranny or under the surrounding puparia; and it is whilst they are in this state

that careful observations can be made of the anchor-process, &c., for attempts to dissect them from the puparia entail a great loss of time, and not unfrequently of temper also!

Mr. G. Palmer has after each harvest sent to me a sack of screenings, from which I have picked great numbers of puparia, and from these the larvæ in their final stage have crawled, most of them to a quiet corner, to lie dormant until April or May, when they change to pupæ; but a few change very quickly, and the flies emerge in September.

On May 12th, 1888, I picked out about thirty puparia from the 1887 harvest, placing them on white blotting-paper over damp sand; five hours after a larva was working its way out, followed by others in an hour or two, and several more the following day (the 13th). One of these began to alter in shape, the body *elongating*, losing the wrinkled appearance, until it had, on the 14th, at 6 a.m., almost regained its full-fed larval form; the skin being quite tight, the mouth-organs drawn down from the end to a ventral position, and all so tight and stretched that it looked like bursting; when at 3 p.m. I placed it under the microscope to make a sketch of it. Between 8 and 9 p.m. it began twisting and straining, particularly its head, which was moved backwards and forwards, until at last, at 9.30 p.m., the skin split over the mouth and towards the thorax; this effort was followed by a short rest, then more twisting, until the larva-skin, with its anchor-process, was gradually worked down the abdomen, and it rested a shrivelled mass around the anal segments, revealing the *true pupa*, which at first was perfectly white, with the exception of a brown chitinous projection not unlike a parrot's beak, occupying the place of the cast-off "anchor-process." No limbs or segments were visible until twelve hours after, when it began to assume a most delicate pink colour; the sutures of the head and thorax appeared but very indistinctly. Three days after, May 17th, the pink colour was decidedly darker, bringing into view the wings and leg-cases. Fourth day: the pupa quite rosy, the thorax testaceous. Fifth day: I made careful drawings under the microscope of the pupa in various positions, when *all* the parts were very distinct. These changes went gradually on, and on the eighth day the facets in the eyes became visible, and dorsal plates darker.

On the ninth day the eyes were much darker, and the tips of the feet or claws visible, and the second pair of legs traced under the wings; thorax much darker, inclined to brown.

The next day, wings almost black, and thorax very dark colour, but the eyes were not distinguishable from the other parts. In the evening, when I examined the pupa with side illumination, I could see the hairs on the abdomen, and mark the strong pulsations; the abdomen was much swollen, and the legs projected and stood clean away from the ventral surface.

At eleven days old the dorsal and ventral markings clearly seen, the ventral segments of a blood-red colour, with scales on back very plain and dark; at night, when examining this and other pupæ, I noticed that they were very susceptible to the light from the side reflector, all twisting and twirling about directly it was concentrated upon them. At 9 p.m. the skin of the abdomen appeared silvery, as though the internal moisture was absorbed.

On the twelfth day, at 5 a.m., the pupa was quiet, with the exception of a slight quivering of the tail; but on the following day, at 4 a.m., it commenced writhing about for a quarter of an hour, then a rest, followed at 4.45 by tremendous muscular efforts, and at last it succeeded in bursting its shell, the female fly gradually working its way out. From the number of larvæ I have watched change to pupæ, and then on until the flies emerged, I find the time varies from twelve to thirteen days for both sexes. One peculiarity I noted was the *time* at which the larvæ changed to pupæ—in nearly every instance between 9 p.m. and 3 a.m.

On August 3rd, 1888, I bred a male Hessian Fly from eggs laid June 2nd, giving sixty-three days for the entire transformation.

For the sake of convenience, I placed a certain number of free puparia in flower-pots filled up to within three-quarters of an inch of the top with damp sand, covered with white blotting-paper. On this I laid the puparia in rows, examining them every morning to see at what time the flies emerged; after many mornings' close watching with a hand-magnifier, I found some just expanding their wings at 3.50 a.m., and, though I have watched as soon as daylight appeared, I never found any out at an earlier hour; the greater number came out between 5 and 7 a.m., and others in the afternoon up to 7.30 p.m.

On May 28th, 1889, I was much pleased to find an empty pupa-case protruding from the top end of one of the infested straws (which I generally cut from 1 in. to 1½ in. above the bend), and another pupa-case sticking out below the bend. Since then I have found several of these "climbing pupæ," which work their way up between the leaf-sheath and stem until they reach an opening; these observations fully confirm those made by Asa Fitch.

The great power the pupæ possess to force their way up was shown in the following experiment: on April 18th, 1888, I buried twenty-four infested straws one inch deep in light soil, exposing the pot to all sorts of weather, and on June 11th I found a female fly on the gauze covering; it had managed to find its way through the earth somehow, but, as I could not find the empty pupa-case, I cannot say whether the fly or pupa ascended. On July 3rd I examined the buried straws, and found several puparia, one containing a pupa about four days old.

Having now seen almost every transformation, I was most anxious to observe that of the fly from the pupa *in situ*, and for this purpose I arranged a number of infested straws stuck into pots of damp sand, and in such position that I could examine each one easily and *quickly*, for the first appearance of a pupa might take place in, say, the No. 10 pot while I was going over No. 1; in fact, this happened repeatedly, until on June 7th, at 6.45 p.m., after numerous hours of morning and evening examination, I was fortunate in focussing my magnifier upon a straw which seemed to shake very slightly. I continued watching it, and in another minute or two I saw the cuticle of the leaf-sheath begin to swell at a tiny point just above the joint, as though something was pushing it outwards and *downwards;* presently a small brown beak-like process appeared and disappeared, but as quickly came into view again, as it made a forward curved movement, the hard, sharp, chitinous beak cutting through the sheath, which was soon widened sufficiently to permit the pupa working its thorax through; then a rest, followed by slight twisting and contortions, until the leg-sheaths were free and rested against the side of the stem, so forming a wonderful bracket or support. The leaf-sheath had partially closed, and gently nipped the end of the pupa, and so preventing it falling out—another of those perfect provisions of Nature which cannot fail to excite feelings of intense wonder and admiration

in the hearts and minds of those who are content to follow closely these marvellous transformations.

The pupa now commenced to bend its head down several times, when the skin burst at the top and back of the thorax, from which the fly (a male) slowly and majestically seemed to rise, until it had protruded as far as the eighth segment, the antennæ, wings and legs being pressed closely around it.

It now commenced bending backwards and forwards, occasionally stopping to give a peculiar sort of lifting movement, after which it succeeded in withdrawing its antennæ, moving them up and down; continuing the back and forward movements, it partially released its wings, and began to draw up its legs from out their delicate sheaths, making great muscular efforts to release its wings, until at last one became free, then renewed exertion to get its legs out, the femora of the first and second pair projecting in front; the other wing was next released, and both hung over the back like two bits of stick; then first leg free, then the second; the antennæ during these contortions had been gradually expanding their whorls of hairs; the third pair of femora now began to project, and the fly looked as though it might fall out and be injured; but just when the second pair of legs were quite free, it swung them about until one caught hold of the stem, towards which the fly immediately drew itself until it had a firm hold, when it quickly withdrew the remaining pair of legs, becoming quite free and walking along on the under side of the bent straw, hung attached by its first and second pair of legs, with the abdomen perpendicular, and the claspers on the tail in the same position; the stick-like wings were flapped together over its back a number of times, and in a quarter of an hour were fully expanded, and then crossed in position; the anal claspers turned up over the back, the tips bent downwards, and at 8.30 p.m., or exactly an hour and a quarter after the straw was split, the fly made its first flight. The tiny silvery shroud or pupa-case is left still protruding from the straw. I have watched flies, both males and females, emerge from isolated pupæ, many of which had great difficulty in freeing their legs from their delicate sheaths, and often became helpless cripples; and yet some of them will manage to crawl to a plant, and lay their eggs in one place; one of these laid eighty eggs on one leaf. Three

or four hours after emerging the males become very restless, flying about in search of a partner; the females hang to the under side of the leaves, with the ovipositor fully extended, and, unless disturbed, they appear very sluggish; copulation usually takes place about noon, and only for a few seconds. Immediately after, the female flies to the young plants or fresh leaves, and commences ovipositing; she generally alights on the leaf, and quickly crawls to the upper side, keeping her head towards the tip of the leaf; she taps the surface with her antennæ, and, arching her abdomen until the tip touches the leaf, she appears to give it a wiping movement towards her head, and in so doing extrudes an egg from the orifice, which is, you will notice, not quite at the end; this action she continues, tapping each time with her antennæ and keeping her head down; sometimes she alights on the stem, and crawls up until she reaches the edge of the leaf-sheath, when she arches the abdomen so much that the tip is brought between her front legs, and she seems to push the eggs in between the leaf-sheath and stem; at other times she will lay them right up to the tip of the leaf. When once a female has started ovipositing, she continues at it in the most business-like manner, passing from plant to plant until her task is done, when she appears weak, often having lost or broken one or two legs, frequently laying her eggs on the stem just above the ground, and then, when quite exhausted, she hides away in the earth to die. They are very careful to avoid ovipositing on mouldy leaves, and when at rest both male and female keep the tarsal joints and abdomen close down to the surface of the leaves.

On Aug. 6th, 1888, I bred one male and three females from one pot of puparia; these I placed under a muslin cylinder enclosing young barley plants, upon which I observed each female ovipositing, and *all* the eggs hatched on Aug. 12th.

On Aug. 8th three more virgin flies were put with *one* male, and with the same result, *viz.*, that all the eggs laid hatched four days after.

On the 7th I found six females out in one pot. I placed these under another cylinder containing *one* male, and again with the same result, each female ovipositing on separate plants, which I most carefully marked, and when examined on the fourth day, *all* had hatched.

These and other experiments proved that *one* male is capable of impregnating from one to *six* females. I have noticed females ovipositing at 6 a.m., and as late as 7 p.m.

During July and August I bred a great number of females, so determined to see whether they were parthenogenetic. I placed half-a-dozen of these virgin females in separate phials, upon the sides and corks of which all oviposited after a few days, but all these dried up in less than a week.

On May 21st, 1889, five virgin flies were "calling," and all laid a number of eggs, which I examined most carefully under my microscope, but could not see any change. I examined them each day until June 5th, when all were shrivelled up.

I isolated a great many virgin females, but not one of the many hundreds of eggs laid ever hatched, so I conclude that the Hessian Fly is not parthenogenetic. I put four females bred May 20th, 1889, under a cylinder with young barley plants, and they continued to "call," keeping the ovipositor slightly in motion and fully extended for two or three days, but apparently came to the conclusion that there were no partners to be had, so they commenced ovipositing, and all died by the fifth day.

From the behaviour of the females in captivity, I should say that they were very shy in their habits, hiding under the leaves and flying but a short distance above the ground; for though I have repeatedly swept the stubble and young growing barley, only once (Sept. 23rd, 1887) did I obtain a female. I have frequently observed them hide away in holes and crannies in the earth, also that they are particularly fond of resting there, their colour, I think, protecting them from being readily seen by birds. The males fly long distances, as proved by those which I captured on the windows of Bownham House, Stroud, Sept. 22nd, 1888, the nearest barley or wheat field being about three-quarters of a mile away.

My own observations fully confirm all that Prof. C. V. Riley and others have stated concerning the weather most favourable for the development of the Hessian Fly. A warm, damp, "muggy" atmosphere is decidedly the best; the larvæ thrive quickest in moist and rainy weather, and the puparia appear as though they could

stand any amount of wet; the pots in which I have kept isolated puparia and those with the infested straws have frequently been flooded for hours together an inch deep, without sustaining the slightest injury; in fact, moisture is of most vital importance to their existence.

On Aug. 9th, 1889, in a letter to the 'Echo,' I expressed an opinion that, owing to the wet weather and backwardness of the wheat and barley crops, there was every probability of being three broods instead of *two*, the second brood emerging early in August; these laid their eggs on young plants, and some of the flies of the third brood did emerge in September.

Though moisture is of such importance to their welfare, and hastens their development, it is astonishing how very tenacious they are of life. In season of drought their development may be greatly retarded—far longer than even Herr Wagner appears to have observed, for he states that "The first part of the Hessian Troops left Cassel in March, 1776, landing in Long Island Aug. 12th; the packing straw used by them must have been that grown in 1775, and in the ordinary course of Nature the pupa which might have been in the straw ought to have hatched April and May, 1776, and the flies of course died *before* reaching Long Island." This would have been correct, supposing all the flies had emerged; and though it is a matter of very small importance whether the fly was introduced into America by the Hessian troops, or from some other source, the following *facts* will show that under certain conditions the development of this insect is frequently retarded to a very long time, or more than *twice* as long as Herr Wagner states.

On March 9th, 1889, I received from Mr. Palmer two sacks of barley screenings, one from the harvest of 1888, and the other from 1887; this one, Mr. Palmer informed me, had been tied up all ready to send to me, but from some cause had been put away in a dry room and forgotten until sending the 1888 screenings, from which, on April 25th, I picked a large number of puparia. I then examined some from the 1887 crop, and was astonished to find several alive! though very much shrivelled; and out of a hundred puparia which I dissected, sixty-seven had dried up; from eighteen the parasites had emerged, and in fifteen the larvæ of the Hessian Fly were still alive, shrivelled up to half their natural length. I placed these on damp sand, and two

days after the resuscitated larvæ had worked themselves out, having, since they were placed on damp sand, imbibed sufficient moisture to enable them to apparently entirely recover from their long imprisonment. These, with a number of others from the 1887 screenings, were placed in the usual manner on blotting-paper on damp sand, so that I could observe all changes. On May 14th I noticed one of the larvæ had assumed a faint rosy tint, such as is seen on a three-days-old pupa; and such this proved to be, though when placed under the microscope I discovered that the larva had not cast its skin, the anchor-process and everything else being still in place. In the course of two or three days I observed that most of the other larvæ had changed colour, and in each instance the larva had been unable to cast the skin; and yet, in spite of this impediment, the changes in the pupæ went on, and were plainly visible.

On May 24th, 1889, the first abnormal pupa had, after twisting and rolling about a distance of two inches, managed to cast its larval skin; and a day or two after the thorax split, but the fly did not seem able to emerge, and died *in situ*. Others seemed to arrive at maturity, and yet not one of these skin-clad pupæ produced a fully-developed and perfect fly. In another pot I placed a number of 1887 puparia just as I picked them out, and from these a perfect male Hessian Fly emerged May 9th. The rest of the screenings I put into a flat box under a large muslin tent out in the garden, where they were exposed to all sorts of weather, with very heavy rain.

On June 3rd the first male emerged, followed by a number of both sexes until July 2nd, when the last (a female) made her appearance. I had sown some barley under the tent, and upon this being pulled up I found a number of larvæ of various sizes about the crown of the plants. Now, if we put down May 15th as being *about* the time when eggs are laid by the first brood, we find that some of these Hessian Flies bred from 1887 harvest had been quite two years in the puparia!

Having now given the result of my observations upon the life-history and economy of the Hessian Fly, I will endeavour to show that something might be done to keep down and arrest the increase of this most injurious insect.

In the first place, I beg to call your attention to

copies of the results of my various collections of puparia, giving the dates when the flies and parasites emerged.

On Aug. 5th, 1887, in answer to an invitation from Mr. Palmer, who asked me to come and examine his fields, I paid a visit to the now well-known Revell's Hall, Hertford. The barley was in splendid condition for examining, and I had no difficulty in picking out the infested straws, for they were very plentiful, and in two hours I had cut over three hundred.

Aug. 8th. I searched another field, but, before doing so, I proceeded to mark out with net-sticks and umbrella a distance of twenty yards up the rows. Starting to walk slowly between these, I examined three rows at either side, cutting with a large pair of scissors the bent straws into lengths of about two inches, counting and placing them in a bag slung round my neck; arrived at the distance-stake, I noted down the result, moved the stake further along, and resumed my work "all among the barley"; but I did not feel at all "*free*" (as the well-known glee goes), for the barley "haulm," as most folks know, has a peculiar knack of getting up the sleeves, and, after travelling about, emerges at the neck. At first this was decidedly irritating, but, as "familiarity breeds contempt," I soon got used to it, and went on with my search, until the sound of a country church clock striking the hour told me I had worked just four hours, during which time I had traversed a distance of eighty yards by twenty, and cut over 800 straws, each of which contained from one to four puparia. From these I bred 280 Hessian Flies and 358 parasites of various kinds.

In 1888 I made collections on July 5th and 17th, and on Aug. 3rd and 15th, spending about four hours each time in cutting the bent straws; and though wet weather interfered a good deal with my operations, I obtained 1458 infested straws. In addition to these, Mr. Palmer sent to me two bags of screenings, one from 1887 harvest, which I have already described, and the other from 1888 crop; and from this, after many tedious hours' work, much lightened by the help of my wife, we picked 1694 puparia, more or less injured by the thresher, but, in spite of this, 261 Hessian Flies and 319 parasites emerged.

During the year 1889 the weather was so bad that I had only one day's collecting, and then my search was stopped several times by heavy thunderstorms and drenching rain, rendering a barley field anything but a

dry spot to be in; this, in conjunction with the laid barley, made my task a hard one, and yet I managed to obtain 500 bent straws, and, had the weather been finer, I could easily have obtained twice that number. Mr. Palmer sent me another sack of the screenings from this harvest, the puparia being so plentiful that in one hour I picked out 270, the largest number ever found in that time, and, from what Mr. Palmer told me, and my own observations, I think the attack was the most serious I had yet seen.

The sum total of infested straws and puparia collected in two years was 4451, from which I bred 752 Hessian Flies! and 909 parasites. All the flies I killed and used for microscopic investigation, and of the parasites I have turned a large number down in infested districts.

HESSIAN FLIES AND PARASITES BRED FROM 1309 PUPARIA COLLECTED IN THE STRAW, AUG. 5TH AND 8TH, 1887.

DATE.	HESSIAN FLIES.		PARASITES.		TIME OF EMERGENCE.	WIND.	WEATHER.
1887.	♂	♀	♂	♀			
Aug. 7			1				
10				1			
11			2	1			
14			1	1			
18				2			
19				1			
21			2	1			
24			3	3			
25				2			
27				3			
29			4	11			
30			1	6			
31			1				
Sept. 1			4	3			
3				1			
9			1				
11		1			4 p.m.	W.	Dull.
17				1			Dull.
18		1			7 a.m.	W.	Dull.
23				1			
28				1			
1888.							
April 28			1	1			
May 16			2				
18			3				
19	1		2			N.W.	Warm.

Date.	Hessian Flies.		Parasites.		Time of Emergence.	Wind.	Weather.
1888.	♂	♀	♂	♀			
May 20	1		2			N.W.	Warm.
21			1				
22	1	2	1	3	4 a.m.	S.E.	Dull.
23	1				6 a.m.	E.	Windy.
24	3	5			6 to 7 a.m.	E.	Windy, very bright.
25	2	6		2		E.	Dull and cold.
26	1	1	3	2		E.	Cold.
27	4	1		2	6 a.m. to 7 p.m.	E.	Cold.
28	5		2	1		E.N.E.	Cold.
29	1	1	1	2			
30	2	2	8	7		E.S.E.	Rain and warmer.
31	1	1	3	4		S.W.	Rain and warmer.
June 1		2	3	2		S.W.	Sultry and dull.
2	2	3	5	2	3 p.m.	S.W.	Sultry & very warm.
3	1		9	13		S.W.	Sultry & very warm.
4	1		10	10		S.W.	Sultry & very warm.
5		1	7	2		N.E.	Cold and dull.
6			9	3			
June 7	3		5	1		W.	Fine to rain.
8	1		2	8	7 a.m.	W.	Rain.
9		1	1	3	3.50 a.m.	W.	Rain.
10			3	3			
11		1	4	6			Cooler.
12	1		9	16			Finer.
13		1	4	5			
14			4	14			
15	1			5		W.	Much rain.
16			3	3			
17				6			
18			1	4			
19			3	1			
20			1	1			
21			1	1			
22			4	1			
23			2	9			
24				3			
25		1	1	1			
26				1			
27		1		7			
28		1		1			
29				1			
30			1	3			
July 1				1			
2				1			
4		1					
6				1			

Date.	Hessian Flies.		Parasites.		Time of Emergence.	Wind.	Weather.
1888.	♂	♀	♂	♀			
July 7				2			
12				2			
23			1				
29	2						
30	1	2					
31	7	4					
Aug. 1	1	7			3 a.m.	E.	Wet.
2	14	1			6 a.m.	W.	
3	6	7			6 a.m.	W.	Glorious day.
4	12	9			4 a.m. to 6 p.m.	W.	Glorious day.
5	5	10			2 p.m.	W.	Fine.
6	1	10			4 a.m. to 6 p.m.	W.	Dull and wet.
7	4	8				W.	
8	2	5				W.	Very close & sultry.
9	7	9	1			W.	Very close & sultry.
10	5	4				W.	Very close and rain.
11	8	13				W.	Very close.
12	4	4				W.	
13		2				W.	
16		1				E.	
20			1				
21				1			
23			1				
24				1			
25			1				
Sept. 13	1	1					
14	1	1					
15	1			1			Fine and muggy.
16	4	6	1	1	6 a.m. to 6 p.m.	W.S.W.	Muggy to rain.
17	2	4					Dull and cooler.
18	3	1				N.W.	
19	4	5				E.	Fine.
20		3				E.	
21	1					E.	
Oct. 27				1			
♂	129	151	147	211			
♀	151			147			
	280			358	Parasites bred.		
				280	Hessian Flies bred.		

Total ... 638 Flies and parasites bred from 1309 puparia collected in straw during 1887.

Hessian Flies and Parasites bred from 1458 Puparia collected July 5th to Aug. 15th, 1888.

Date.	Flies.		Parasites		Wind.	Weather.
1888.	♂	♀	♂	♀		
July 25		1			W.	
26	1				W.	
27	1				W.	Wet.
29	1	1			W.	
30	2	4			W.	Fine to wet.
Aug. 2	1				E.	
4	1				W.	
5	1	1				Wet.
16		1				
19		1				
20			1	1		
22		2		1		
23		3	1	1		Wet.
24		1	1			Fine.
25		1				
27				2	N.	
29		1		1	N.W.	Wet.
30				1		
31				2		
Sept. 1				1		
2		1			N.W.	Wet.
3				1	N.W.	Wet.
5			1	1	N.W.	Wet.
6	1		1	1	S.W.	Fine.
7				1	S.W.	Fine.
9		1		1	E.S.E.	Wet to fine.
10				1	E.	
12			2		W.S.W.	Fine.
13			1	1	E.S.E.	Fine.
14			2	1	E.S.E.	Fine.
15		2		1	N.N.W.	Fine.
16			3	1	N.N.W.	
17	1			1		
18				1		
19	1					
20				1	E.S.E.	
21		1				
22		1				
23	2	1	1		N.E.	Dull.
24		2	1			Dull and muggy.
25			1	2		
26				1		
27				1		
Oct. 1				1		
2			1			
15			1			
22				2		

Date.	Flies.		Parasites.		Wind.	Weather.
1888.	♂	♀	♂	♀		
23				1		
27				2		
Nov. 26			1			
1889.						
May 17						Cool.
18		1				
21	2					
22	1	1			S.E.	Warm.
23	2	2				Sultry.
24	2	4			S.W.	Sultry.
25	3	3			S.W.	Warm.
26	2				S.W.	Wet.
28	2	1			S.W.	Wet.
29	11	6			S.W.	Wet and cool.
30	1	2		1		
31	3	9			S.W.	Wet and cool.
June 1	3	14				Warm.
2	8	15			S.W.	Very warm.
3	7	7			S.W.	
4		9			S.W.	
5	3	7				Dull and warm.
6	3	5			N.E.	Dull and cool.
7	6	3	4		N.E.	Very cold and wet.
8	1	5	2		N.E.	Much cooler. [50°.
9	1	2	1		N.E.	Very much cooler:
11	3	1	2		N.E.	Dull and dark.
12	1		1			
13		1	4	1	N.E.	Dull and dark.
14		1	6	1		Dull and cold.
15			8		N.	Dull.
16	1		3	3		
17			9	3	N.W.	Warm.
18	1		4	2	N.W.	Warm.
19			6	5	N.E.	
20			6	4	N.E.	
21			8	8	N.E.	Rain.
22			6	7		
23			6	6	N.	Very warm.
24			2	3	N.E.	Warm.
25			4	4	N.E.	
26			2	4		
27	1		3	3	N.E.	Very warm.
28			2	4		
29	1		2	2		Very warm.
30			1	5		
July 1				1	N.W.	Cooler.
2				1		
4				4	N.	Cooler.
5			1	1	S.E.	
7			1	5	W.	
8				2	N.E.	Cool.

Date.	Flies.		Parasites.		Wind.	Weather.
	♂	♀	♂	♀		
9				2	W.	Rain.
11				1		
14				1	W.	Wet.
15				1		
21				1		
Aug. 13	1				N.W.	Wet.
18		1			N.W.	Wet and warm.
Sept. 1	1		1		N.W.	Warm: very hot.
10		1				
♂	84	127	113	119		
		84		113		
Flies		211		232	Parasites.	
				211	Flies.	
				443	Total bred from 1458 puparia.	

Flies and Parasites bred from 1694 Puparia picked from Screenings from 1888 Harvest.

Date.	Flies.		Parasites.	
1889.	♂	♀	♂	♀
May 1			2	
4				1
5 to 9			25	12
				4
7	1			
10	3	4		
11	2	3	10	13
12	2	1	18	16
13	3	5	13	8
14	2			
15	2			
16	2	2		
17	1	1		
18	1	1		
19		2		
14—19			28	28
20	1			
21	1			
22	2			
23	1	2		
24	1	1		
20—24			18	17
25		1		
26		1		

Date.	Flies.		Parasites.	
1839.	♂	♀	♂	♀
May 27	1			
25—27			9	15
28	4	3		
29	2	1		
28—30			8	15
30	2	1		
31		2	4	4
June 2		1	3	
3 & 4	1	2	9	7
5			6	9
11			4	9
14			1	
July 21			1	1
July 26	7	4		
27 & 29	4	4		
30	6	1	1	
31	9	9		
Aug. 1	1	3		
♂	62	55	160	159
♀	55			160
	144	Larvæ.		
				319
	261	Flies.		
	319	Parasites.		
	580	Bred from 1694 puparia.		

Flies and Parasites bred from Puparia from American "Fall Wheat."

Date.	Flies.	
1889.	♂	♀
May 5		1
6	6	2
7	4	7
8	7	7
9	3	5
10	7	3
11	3	4
12	6	3
13	5	1
14	1	
15	2	1
16		2
22		1
♂	44	37
♀	37	
	81	

Date.	Parasites
1889.	? sex
June 5	5
13	10
16	4
July 5	3

22 Parasites bred.

On June 11th I sent over 300 of the parasite, *Semiotellus nigripes*, to Prof. Riley for the purpose of acclimatisation, but owing to the heat, &c., surrounding the mail bags, all died in transit. In the course of February and March I hope to be able to send a large number of puparia picked from screenings, and no doubt from these Prof. Riley and his assistants will be able to breed this exceedingly plentiful and most useful parasite in such numbers that it will soon obtain a footing in the United States, and, I trust, will make its presence felt.

Since reading this paper, I have sent over 2000 puparia to Prof. Riley, of the U. S. Department of Agriculture at Washington, and to-day, May 8th, have received a letter as follows:—"I duly received your favour of April 9th, and the accompanying box of puparia. I am glad to say that these arrived in good condition, and that many of the parasites have already begun to issue; and that I have made arrangements to distribute them at four different points, so that I think the result of this experiment will be satisfactory."

During Sept., 1888, I found the puparia exceedingly plentiful all round the neighbourhood of Stroud, Gloucestershire, which is the most westerly point where "the

pest" has been recorded from; *not* that it had not occurred there before, but there were no persons who troubled themselves to examine the crops. At Acock's Green, near Birmingham, I found puparia in plenty in the barley stubble, together with the rarest thing I have ever met with, *viz.*, a *satisfied* farmer: one who (as he said) "didn't care a straw if the Hessian Fly *was* in his fields; he had had a good crop, and what more did he want? except to have me locked up for trespassing in his fields of stubble"! This specimen of an English farmer had not *always* been so contented; for years ago, so he told me, his crops of mangolds "had been eaten up by the worm as turned to a little mot as lays thousands of eggs in a minute! *he* knew, and had seen 'em do it in his '*at!*'" The remembrance of this "little mot" was indeed bitter to this old ignoramus, who positively raved about it, and wanted to know why "Parlimint didn't do summut to help the poor farmer to live?" I quite agreed with him that something ought to be done, and so we parted good friends.

Another farmer at Evesham had heard something about the Hessian Fly, but "hadn't bothered himself about it," though on examination of the stubble I found the puparia in plenty. I asked, What had he done with the screenings? "Oh, chucked 'em in a heap under a clump of trees" was his reply, and there I found them just as they had come from the thresher; the farmer had made a "midden heap" of them, and that was enough for him; and *more* than enough for others—for the abundant spread of the Hessian Fly over their fields.

On Aug. 24th I wrote a letter to 'The Times,' suggesting the advisability of collecting the bent straws breeding the parasites, to turn down, and of course killing the flies. I argued then, as I do now, that if *one* person can in about four hours collect about 2000 puparia, a properly organised staff would be able to show far more important results; but though several papers noticed and commented on my letter, I believe I was the only person who continued to collect and breed the parasites.

I am afraid that very little preventive work can be done whilst the eggs are being laid; as this takes place from the latter end of April right on to the end of June, and it would be impossible to search the growing barley;

and even *after* harvest, when there are so many self-sown plants, I doubt if it would answer.

During the next stage, the larval, we do not see the result of their work; so we must wait another month, or until, say, the middle of July before we can find the bent straws, when, supposing there was any desire on the part of Government to do anything in the way of checking the pest, the puparia could, as I have already proved, be collected by thousands for the purpose of breeding the parasites.

As an instance of what can and has been done in importing the natural enemies of a most injurious pest, I cannot do better than call the attention of everyone here present to Prof. Riley's Report to the United States Committee of Agriculture on that most injurious pest, the Orange Scale (*Icerya Purchasi*), which, as most horticulturists know, has utterly ruined whole districts of orange-groves in California, &c., and bid fair to make a clean sweep, until its natural enemy was discovered in Australia; and Prof. Riley, acting with that promptitude and "cuteness" which is part of the character of our American cousins, suggested to the United States Commission that agents should be sent out to collect this natural enemy, a species of lady-bird, and in this the Government at once acquiesced; no time was lost in looking out "red tape," but the letter of submittal was made out, and Mr. Koebele started on his journey to Australia, "nothing doubting" or wanting either, determined to obtain the insect for which he was sent; no such thought as, "It can't be done," "It isn't practical," &c., ever entered his mind, but he went on and on, gradually gaining experience and obtaining specimens, which he quickly sent home; these were as quickly placed in a large muslin tent covering an orange tree which was infested with the scale, and here the *Vedalia* set to work to feed and lay their eggs; the larva soon hatched, and commenced feeding upon the *Icerya*, eating and breeding so fast that in a short time there were sufficient beetles to permit of the poor eaten-out orange-growers coming with their boxes, &c., to carry away dozens of these precious "bugs" to transfer to their orchards, with the result that in a very short time scarcely an *Icerya* could be found!

Now that we have a "Chamber of Agriculture," no

doubt our Government will do something of a practical nature to check the increase of these injurious insects; and I am sure that I only express the desire of all present to-night, that more attention may be given to the study of Economic Entomology, and that we are now within measurable distance of the time when the "poor distressed farmer" can go to the Natural History Museum and find comfort in studying the enemies of his crops, and also Nature's provision for the extermination of these pests.

If we want a pattern, we have only to turn to the United States of America, and its Department of Agriculture, with Dr. C. V. Riley at the head of the Entomological Division, aided by his assistants, all of whom seem to have imbibed his spirit. Any farmer, or anyone who is *not* a farmer, who may write to the Department about any insect is always treated in the most courteous manner, and should the letter relate to any insect little known, an agent is sent down to make enquiries, and not many months pass before the life-history and economy is known from beginning to end. I would here mention how very much I am indebted to Prof. Riley for his long-continued kindness and help in my study of the Hessian Fly and its *parasites;* and I would call special attention to that most useful of entomological pamphlets, 'Insect Life,' published by the Bureau of Agriculture, which contains the most practical suggestions relative to Economic Entomology, with numerous figures of insects, and details generally passed over by British entomologists.

No doubt all who are here present will recollect the profound sensation caused among the inhabitants of Great Britain during the autumn of 1886, when the announcement was made that the Hessian Fly had been discovered in Hertfordshire. The newspapers were full of long articles written by learned and *un*learned men, and in the periodicals figures of "the pest" were given; "latest news" and bulletins were issued with surprising rapidity, reporting the advance of the enemy, and that it was gradually spreading; but from this latter opinion I entirely disagreed, and I have not changed my opinion, that in whatever barley field, in whatever county an intelligent farmer or practical entomologist searched, there would be found the puparia of the Hessian Fly; and I quite agree with Prof. Riley that it had been

breeding in Great Britain for some years, and we must confess that it had been overlooked until Mr. G. Palmer discovered it in his barley fields, July 27th, 1886.

In September last (1890), whilst on a visit to friends in the island of Portland, I searched both wheat and barley fields with the usual result, that I found puparia in all of them; the last one visited surrounded the well-known lighthouse at "Portland Bill," the furthermost point on the island, and here the barley was still standing; and five minutes' search revealed both larvæ and puparia in the injured stems; these I showed to the keeper of the lighthouse, who informed me he had "heard tell of the Hessian Fly in the newspapers, but did not know how to go about to find it."

From reports we gather that some of the sleepy British farmers were stirred into activity to search for the pest, and in most cases found it in plenty; but, like all other things connected with Economic Entomology in Great Britain, the interest at first taken in the Hessian Fly has been gradually falling off, until in 1889 there were not (according to reports) a dozen farmers to be found in the whole land who cared one jot whether it was plentiful or not in their fields, though no doubt every one of them would have the usual grumble at the lightness of the crop.

All practical entomologists who have studied the Hessian Fly in the fields agree that the preservation of the natural remedy—the parasites—is of the greatest importance. Perhaps a few quotations on this important subject will not be out of place. Dr. Asa Fitch, who was about the first to study the Hessian Fly in America, asserted that it was of the highest importance to encourage these parasites.

In the 'Third Report of the United States of America Entomological Commission for 1882,' Dr. Packard, when referring to the subject of "burning the stubbles," writes: —"Although this remedy has been advocated, it will be seen to be worse than useless when we reflect that, after all the artificial means taken to reduce the number of the Hessian Fly, Nature's method of checking its undue increase is far more important and thorough-going; we refer to the diffusion and multiplication of the insect parasites. As previously stated, most probably nine-tenths of the young Hessian Flies are destroyed in the

larva or pupa state by the parasites already described. For the most part, these parasites live in the 'flax-seed' contained in the straw, and appear in spring. Now, to burn the stubble in the autumn or early spring is simply to destroy these useful parasites, the best friends of the farmer. We do not hesitate to urge that the straw be untouched. On the contrary, the parasites should be gathered and bred in numbers. and we believe that practical entomologists should bend all their energies towards clearing up the subject of rearing and multiplying these insect hosts. Much knowledge and practical skill is needed in this direction, as occasionally by disseminating the parasites their noxious hosts may be increased and distributed; but knowing, as we do, how many more of the parasites are in many cases bred than the insects on which they prey, it seems safe and reasonable to advise not only not burning the stubble, but letting it stand, so that the *parasites* may finish their transformations, become fledged, and ready, when the eggs and larvæ of the Hessian Fly are upon or in the young wheat, to destroy them. It is a matter of fact that in years when the Hessian Fly is specially abundant and destructive, similar seasons are highly favourable to the corresponding increase in the number of their insect or ichneumon parasites; they do their work so effectually that the few following years the numbers of Hessian Flies are greatly reduced. It is, then, to these parasites that we are indebted for the years of immunity from the the attacks of the Hessian Fly as much as to favourable and unfavourable weather."

Herr Wagner also states that, "The most effectual remedy in checking the excessive multiplication of the wheat-worm has been provided by Nature herself in the aid received from the parasites just mentioned. To spare them is a very important thing."

On July 30th, 1888, I ventured to bring the subject of breeding the parasites before the readers of the 'Mark Lane Express,' for since my letter to 'The Times' I had had another year's practical experience of rearing parasites, so could speak still more positively as to what could be done. This letter was replied to in the following week, Aug. 6th, but in a totally different manner to what might have been expected. I was told, "I was no farmer"; that "there were other difficulties in the

practical applications of the subject, which a non-agriculturist may well be excused for not knowing, &c."; and in a subsequent letter, in reply to mine, the following most extraordinary paragraph appeared, *viz.*, "It does not therefore follow that we are sure of their (the parasites') services; male and female have to meet, eggs be fertilised, and the female must find her way to the infested fields and stalks before the egg can be laid"!

I must confess that I had never read anything connected with Economic Entomology which amused me so much as the remark that male insects have any difficulty in finding the females, and *vice versâ*. Why? Was it not one of the first commands given to animals, "to be fruitful and multiply"? and have we ever heard of female flies experiencing any difficulty in finding out the right place to deposit their eggs? Are they idle and feel "it can't be done," or do they ever forget to use their powers of flight and that most marvellous sense, whether of smell or touch, which enables them to know in an infinitesimally short time in what direction the food lies upon which their progeny must feed?

If they were under the guidance of a Committee, no doubt they would experience the greatest difficulty in these matters; but being the work of the Creator, they are endowed with such powers that they do everything in accordance with His purpose; and whatever purpose or duty they have to perform, their whole life and energy seems taken up in carrying out that purpose. What a lesson is here set forth for us to go and do likewise!

For Explanation of Plate XVI. see next page.

Explanation of Plate XVI.

Fig. 1. Lateral and ventral view of head of larva (one day old) of Hessian Fly, × 140 diam.

2. Lateral and ventral view of feeding larva, × 8 diam.

3. Lateral and ventral view of head of feeding larva, × 36 diam.

4. Lateral and ventral view of puparium, × 8 diam.

5. Lateral and ventral view of third stage of larva, × 8 diam.

6. Lateral and ventral view of 1st, 2nd, and 3rd segments of ditto, showing the head and anchor-process, × 36 diam.

7. Head and anchor-process after having been squeezed flat, × 36 diam.

8. Lateral and ventral view of pupa, × 8 diam.

9. Vertical section through centre of barley-stalk, showing a feeding larva *in situ*.

10. Vertical section through centre of bent barley-stalk; puparium *in situ*.

11. Vertical section through centre of bent barley-stalk; 3rd stage larva *in situ* within the puparium, head *downwards* and *inwards* towards the stalk.

12. Vertical section through centre of bent barley-stalk; 3rd stage larva commencing to turn round.

13. Ditto, ditto, further advanced.

14. Ditto, ditto, half-way round.

15. Ditto, ditto, three-quarters round.

16. Ditto, ditto, larva reversed, showing head *upwards* and *outwards* towards the leaf-sheath.

17. Vertical section through centre of bent barley-stalk; pupa within puparium, and cast skin and anchor-process.

18. Bent barley-stalk; pupa protruding, previous to the fly emerging.

(Figs. 9 to 18 magnified 5 diam.)